

A detailed 3D cutaway diagram of a particle accelerator, likely the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory. The diagram shows the complex arrangement of superconducting magnets, beam pipes, and support structures. The central beam pipe is highlighted in green, surrounded by various colored components like red, blue, and yellow magnets. The entire structure is housed within a large, grey, industrial-looking building.

Brief Simulation Updates

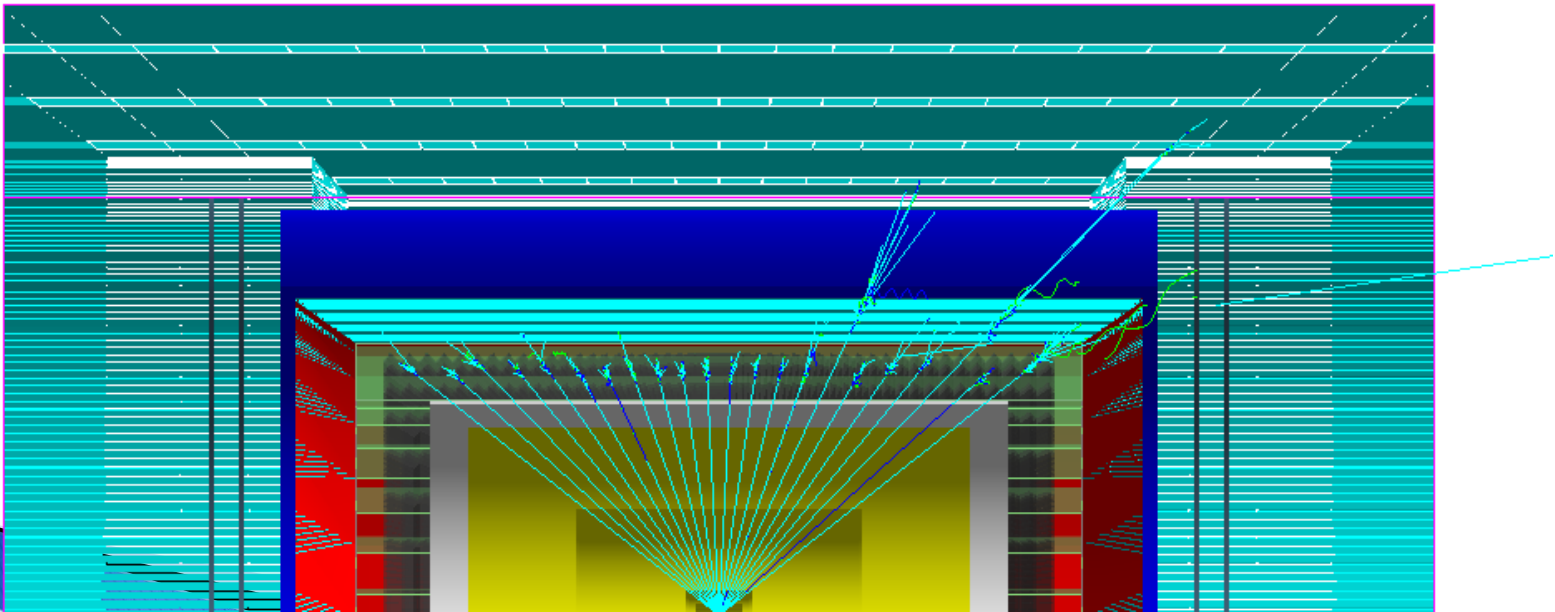
Jin Huang (BNL)

From last meetings:

SPACAL design implementation in Geant4

- ▶ Enabled with new branch 2DSpacal:
 - In nightly build, but not used by default
 - <https://github.com/sPHENIX-Collaboration/macros/pull/2>
 - <https://github.com/sPHENIX-Collaboration/coresoftware/pull/19>
 - Activated with this flag in Fun4All_sPHENIX.C

```
Cemc_spacal_configuration =  
PHG4CylinderGeom_Spacalv1::k2DProjectiveSpacal;
```





48 2x8-tower super modules

Towers project towards IP



Stainless steel SS310
Support box



2x2 2D tapered
SPACAL modules

Gap between modules are also implemented

- 300um tolerance outside super modules skins
- ~2mil between SPACAL and SS skin
- ~2mil between SPACAL modules

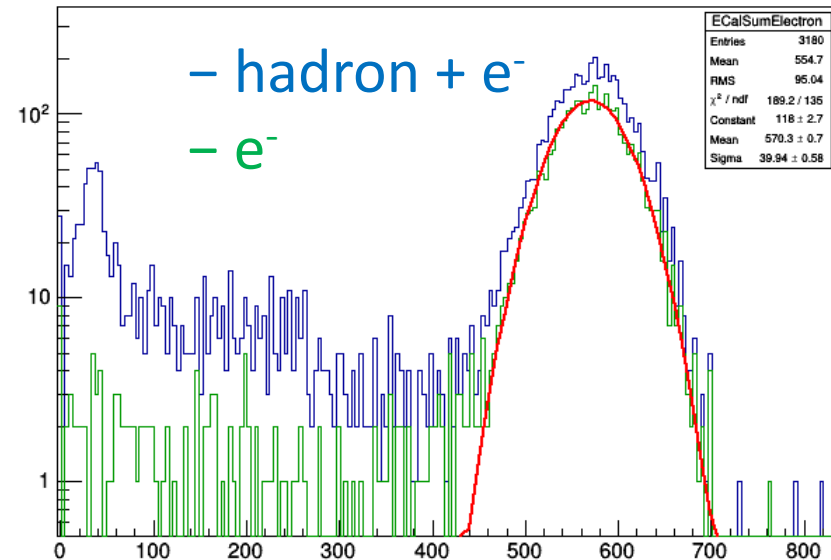
Recent updates

- ▶ Chris produced first few test productions:
 - /gpfs02/phenix/prod/sPHENIX/preCDR/pro.1-beta.2/spacal1d
 - /gpfs02/phenix/prod/sPHENIX/preCDR/pro.1-beta.2/spacal2d
- ▶ Implementation of analyzing Geant4 data in tower structures as built:
 - Tag hits in SPACAL output with sector/tower/fiber IDs.
 - Add a cell builder to group hit in each 10M SPACAL fiber separately in each cell (which allow us to implement fiber-fiber light collection eff. when needed)
 - Update tower builder to take SPACAL cells and collection light yield from each cell.
- ▶ Submitted to use in production:
<https://github.com/sPHENIX-Collaboration/coresoftware/pull/29>

Test beam comparison 1

- ▶ One of the long last concern is lack of beam test calibration for our simulation
- ▶ Obtained eRD1 2014 beam test geometry and data with many help from Oleg Tsai, Alex Kiselev and Craig Woody

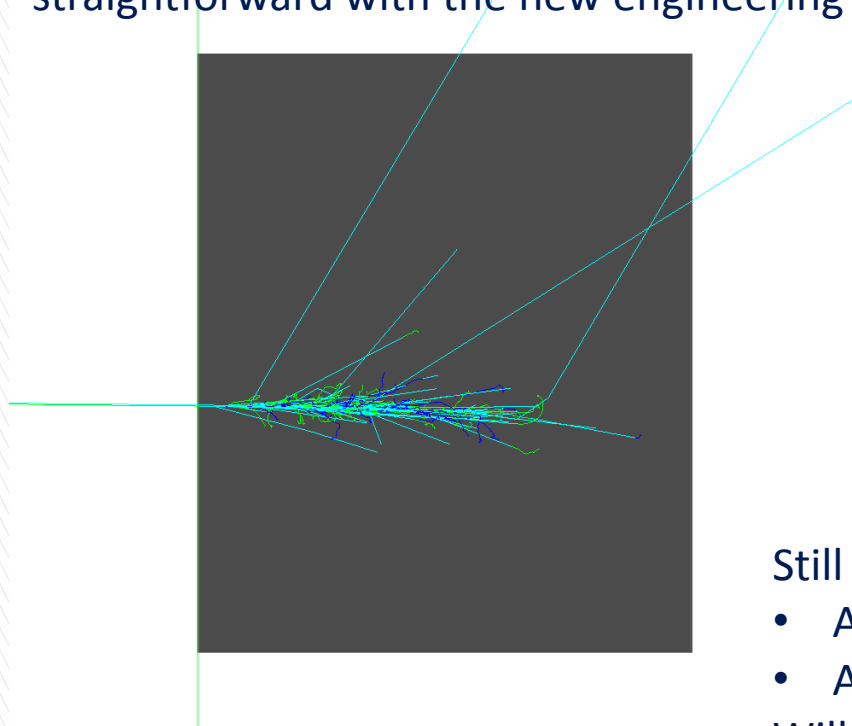
SPACAL prototypes in 2014 Fermilab beam test



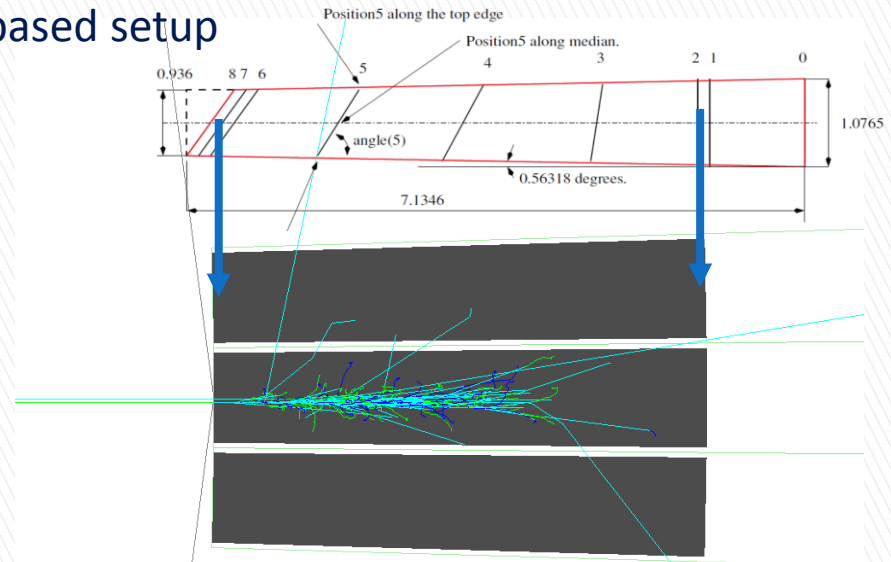
Courtesy : O. Tsai (UCLA)

Test beam comparison 2: 8 GeV electron shower in Geant4

Implementation in Geant4 relatively
straightforward with the new engineering based setup



Side view (non-tapered side)
≈ Z vs R view



Still need:

- Adjust module gaps size
- Add enclosure box (especially front 0.5mm Al)

Will leave the slope cut flat (approximation)

Side view (tapered side)
= beam axis view

Photon analysis and Clusterizer choice

- ▶ Discussed possible photon Clusterizer with Stefan Bathe and Megan Connors
- ▶ Fast pre-CDR solution for photon performance in HI
 - Trying Sasha's PHENIX clusterizer
 - Ideal clustering (group tower around truth photon track)
 - Try `FastJet` with $R = \text{Mollie radius}$?
- ▶ Long term, construct an official package?
 - CMS island algorithm (Thanks to Stefan and Yen-Jie Lee (MIT)):
https://cds.cern.ch/record/687345/files/note01_034.pdf
 - Alice algorithm
 - General purpose package?
 - More volunteers?

Pre-CDR plots

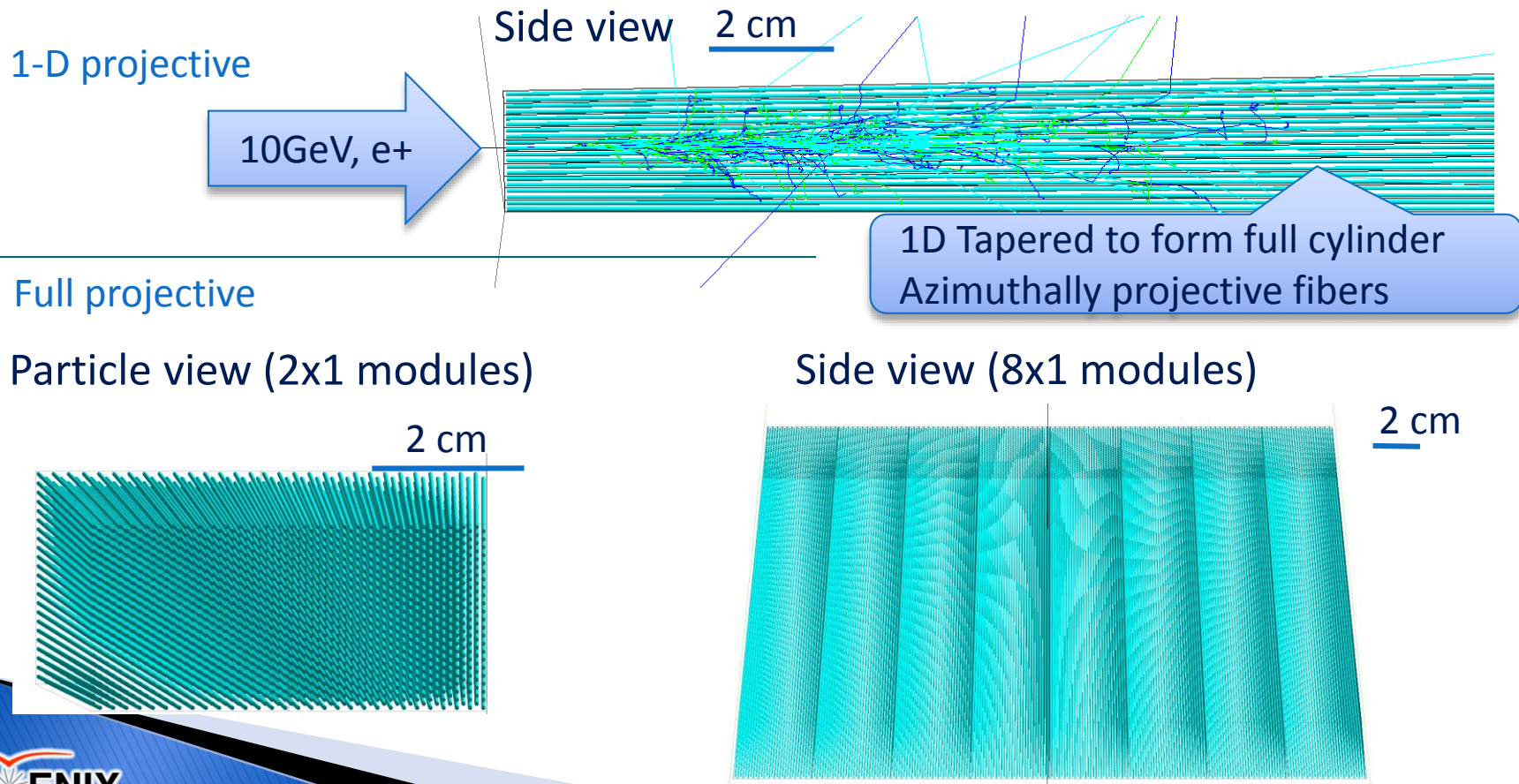
- ▶ Single particle (e/mu/pi/p/gamma/pi0)
 - Line shapes <- need to finish test beam setup
 - Linearity <- need new production with towerings
 - Energy resolution <- need new production with towerings
 - Sampling fraction <- ready to produce plot with test production
 - Dynamic range <- need new production with towerings
- ▶ Au+Au HIJING
 - Underlying event energy and fluctuation <- need new production with towerings
 - Rejection vs efficiency for electrons <- need new production, verify track proj. tools
 - Photon resolution <- need new production, decide the clusterizer
- ▶ EM energy trigger performance
 - Turn-on curve <- need new production, improve last tools

Extra Information



Detail view – Fiber display

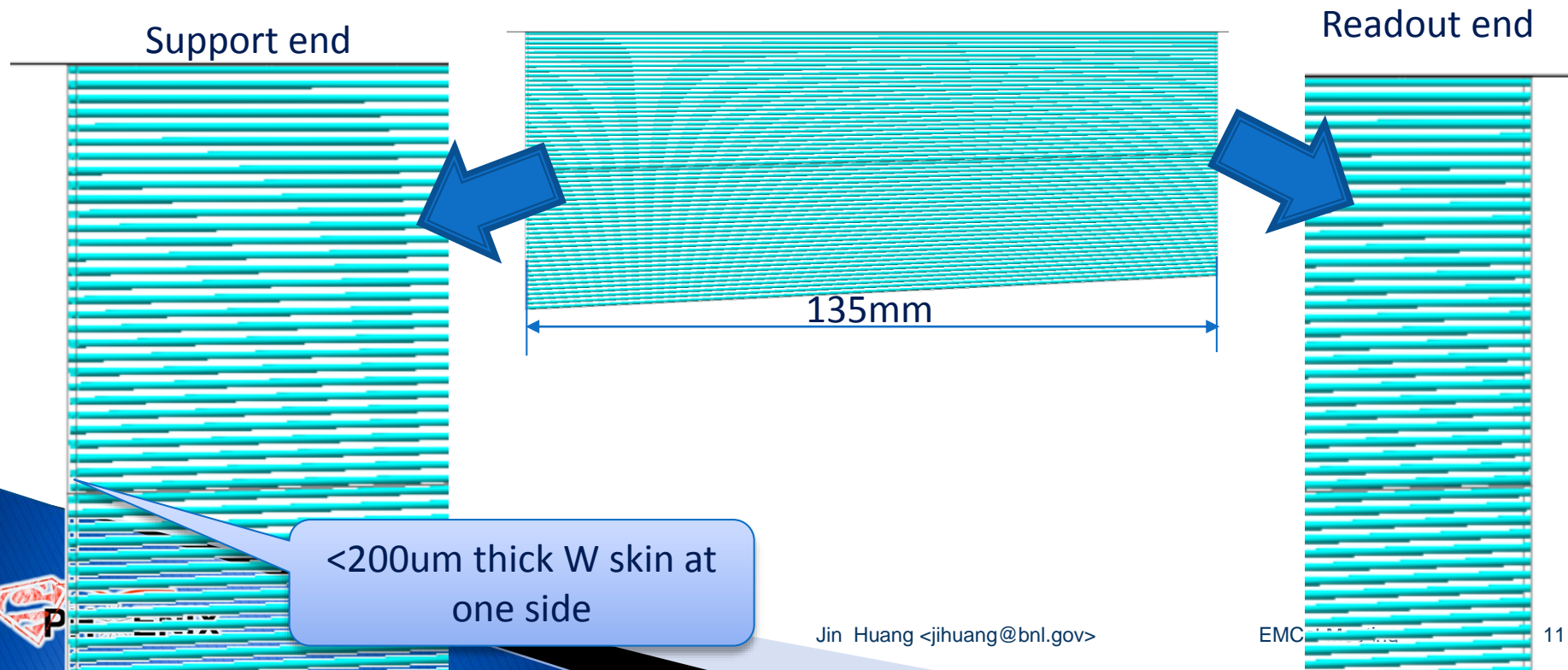
- ▶ Tungsten + Epoxy material: 12.18 g / cm^3 , 96.9% mass with W
- ▶ Fiber: $\phi 440\mu\text{m}$ core (Polystyrene) + $15\mu\text{m}$ skin (PMMA)
 - Thanks to the reference model from A. Kiselev (EIC taskforce & EIC RD1)
- ▶ Fiber matrix is layout in triangle pattern with a nominal separation of 1mm. Fiber at least $100\mu\text{m}$ away from surface
- ▶ Default: 1-D projective in azimuth. New also available for test: full projective module



Detail view –

One trick used to speed up construction

- ▶ Most fibers (~700/module) has different length in each SPACAL module (~400 unique pieces), which leads to large number of logical volume in G4, which take ~5min to construct
- ▶ Tremendously speed up by using same fiber length per module. This leave a <200um thick W skin at the end of the modules. Expect negligible impact to simulation precision.

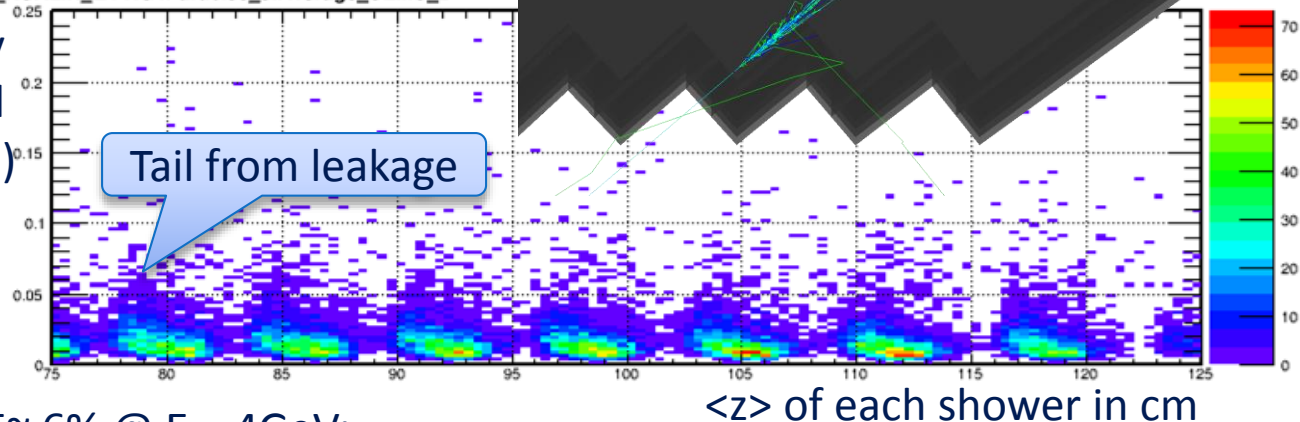


Leakage looks OK so far (vs $\langle z \rangle$). Still in verification $p_T = 4\text{ GeV}/c$ electron in sPHENIX field

Ratio of energy
 in inner HCal
 (scint + abso.)

Total_HCALIN_E/PHG4Particle0_e:Average_CEMC_z

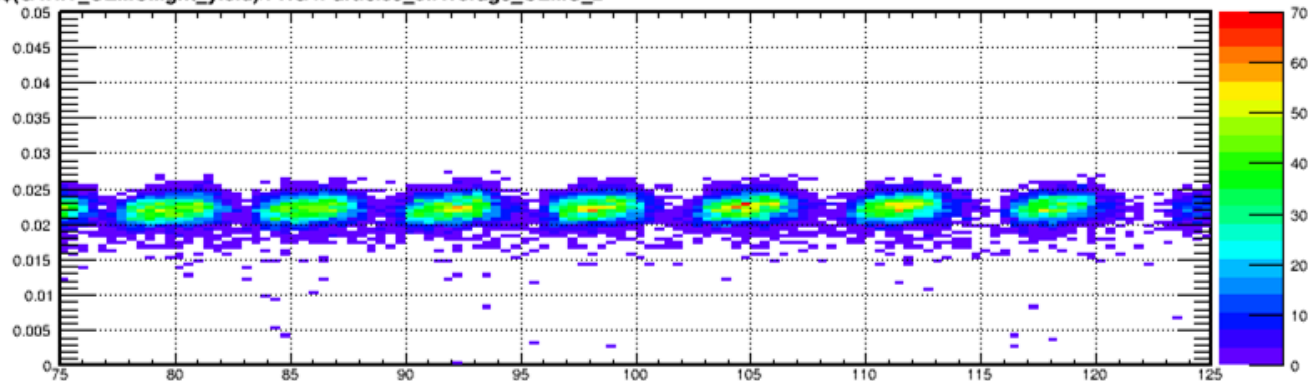
Tail from leakage



In comparison to
 energy resolution $dE/E \sim 6\%$ @ $E = 4\text{ GeV}$:

Ratio of energy
 in SPACAL scintillator

Sum\$(G4HIT_CEMC.light_yield)/PHG4Particle0_e:Average_CEMC_z

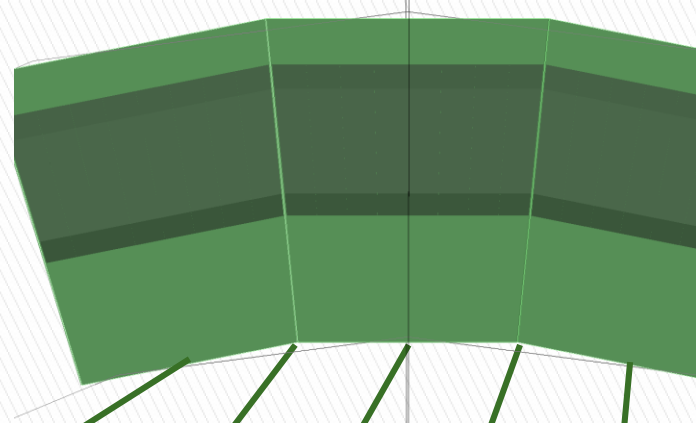


$\langle z \rangle$ of each shower in cm

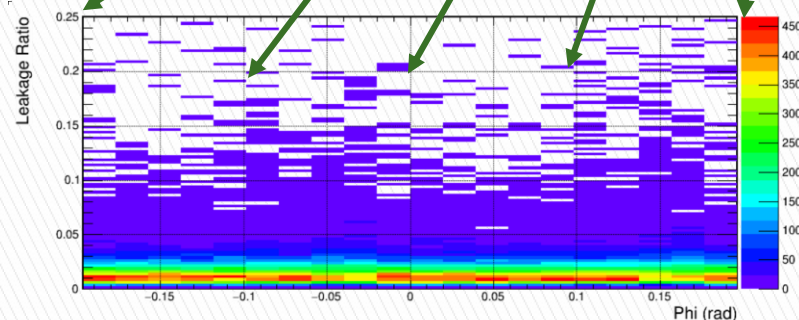
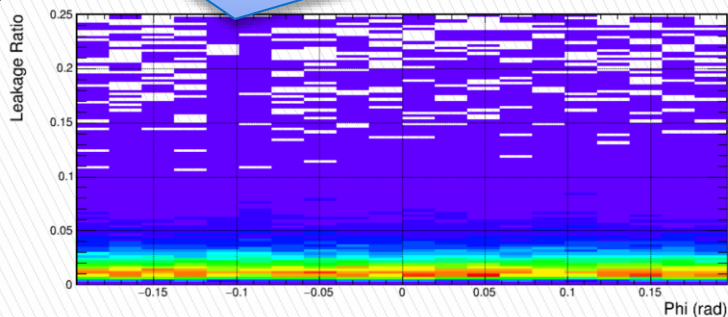
Azimuthal Leakage also not so bad

$p_T = 4 \text{ GeV}/c$ particles in sPHENIX field
 $-5 \text{ cm} < v_z < 10 \text{ cm}$, $0 < \eta < 1.0$

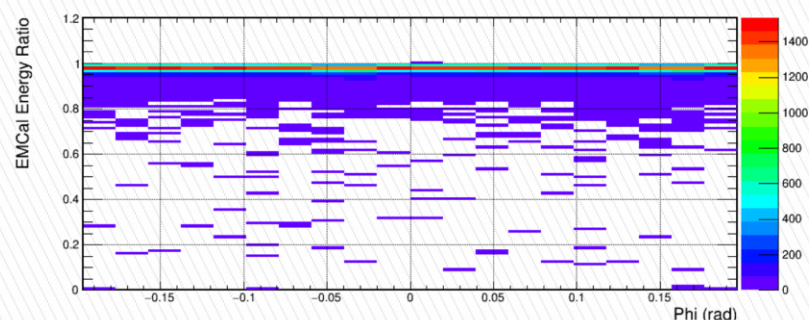
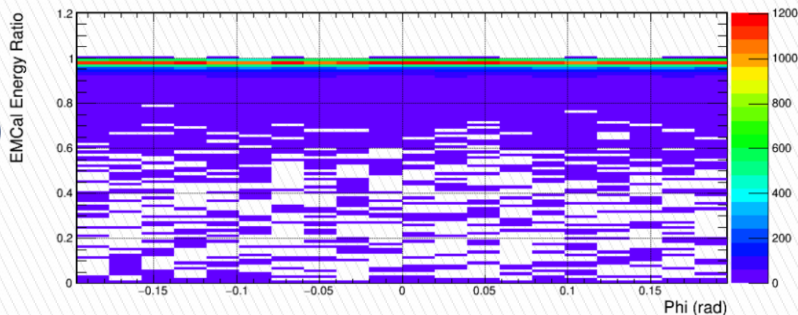
Super module edge:
 600 μm gap over 20cm length
 or $\sim 0.3\%$ azimuthal gap
 acceptable effect: negligible (?) lower photon eff.



Ratio of energy
 in inner HCal
 (scint + abso.)



Ratio of energy
 in SPACAL
 (scint + abso.)



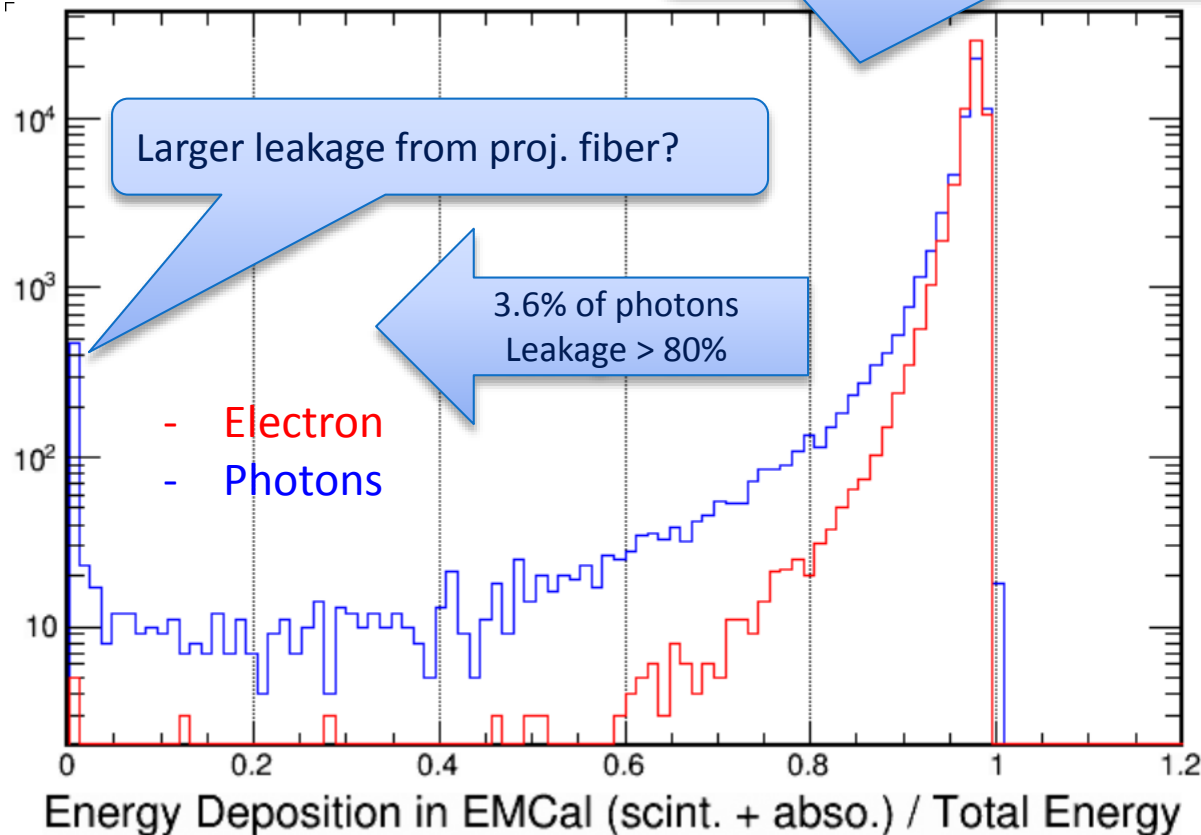
Photons

Electrons

Leakage: integrated over acceptance

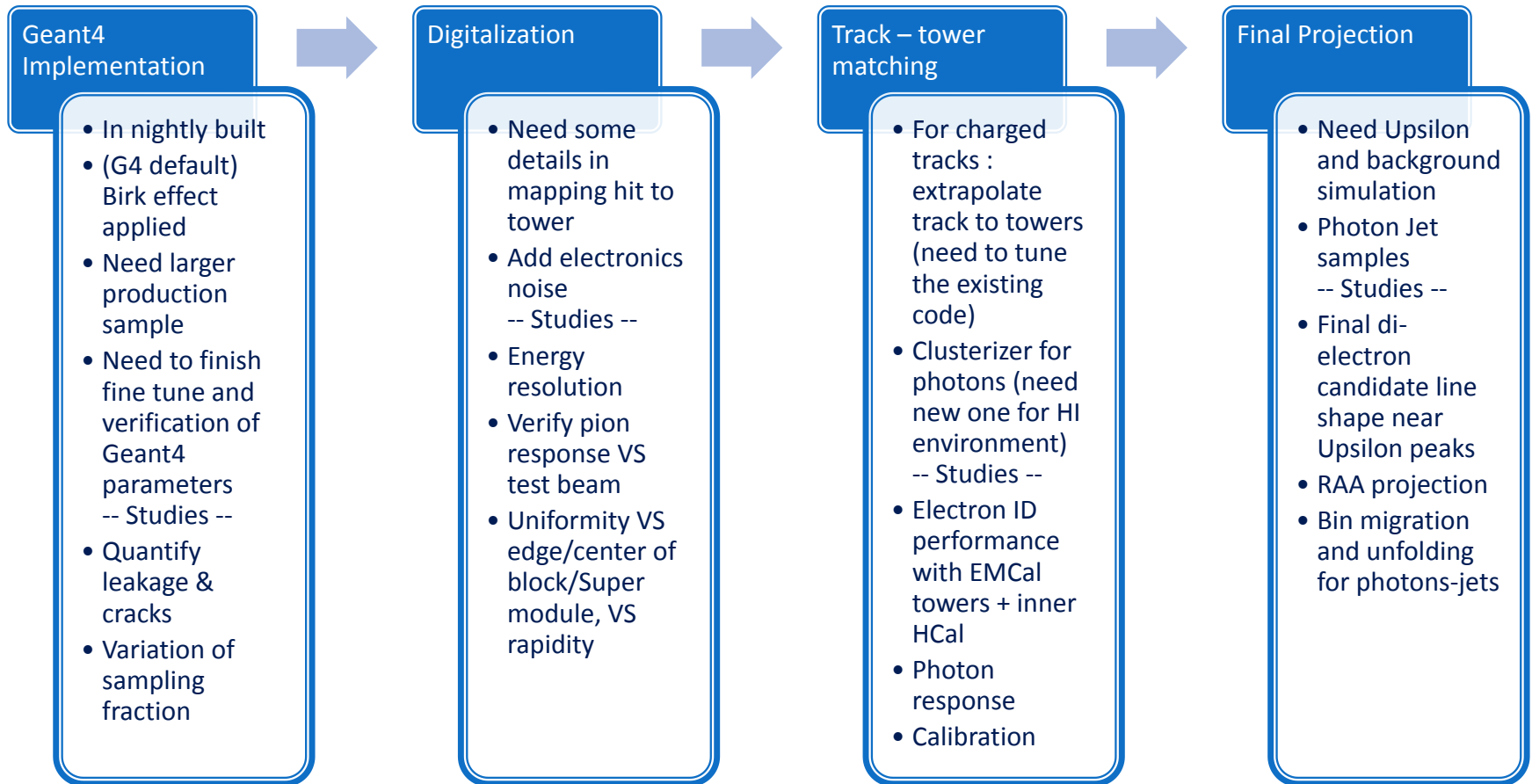
$p_T = 4 \text{ GeV}/c$ particles in sPHENIX field
 $-5 \text{ cm} < v_z < 10 \text{ cm}, 0 < \eta < 1$

8% of photon leave 80-90% energy in EMCal
-> kinematic smearing in gamma-Jet measurements



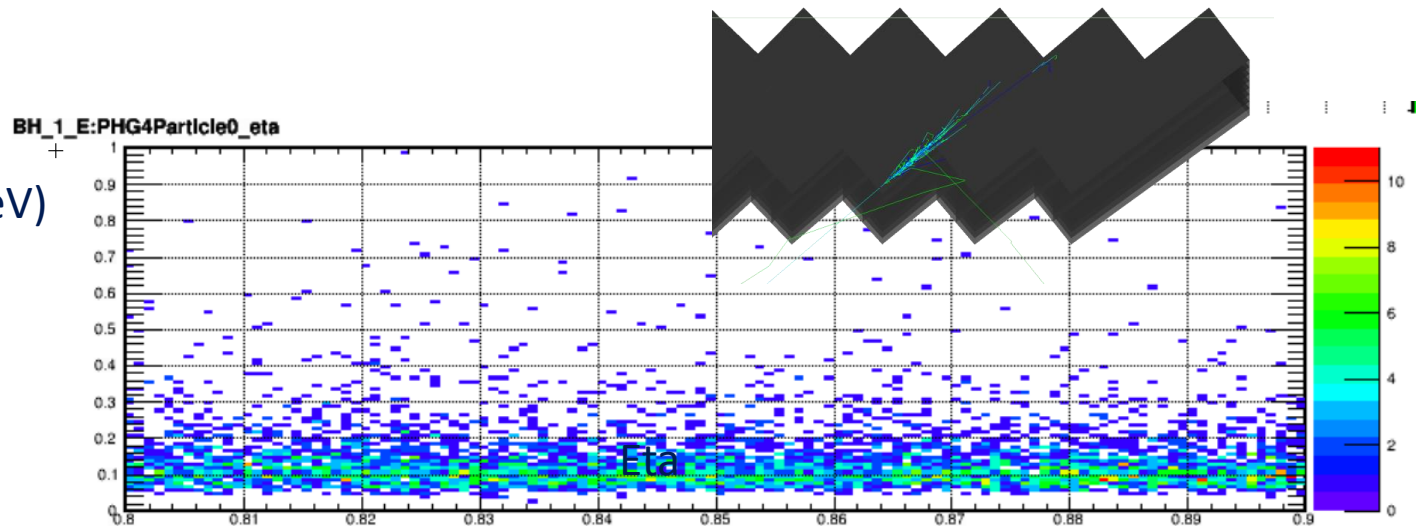
Do we have that with realistic waving fiber?
Solution: Tilt SPACAL by 25 mrad? Inner HCal veto?

Path forward

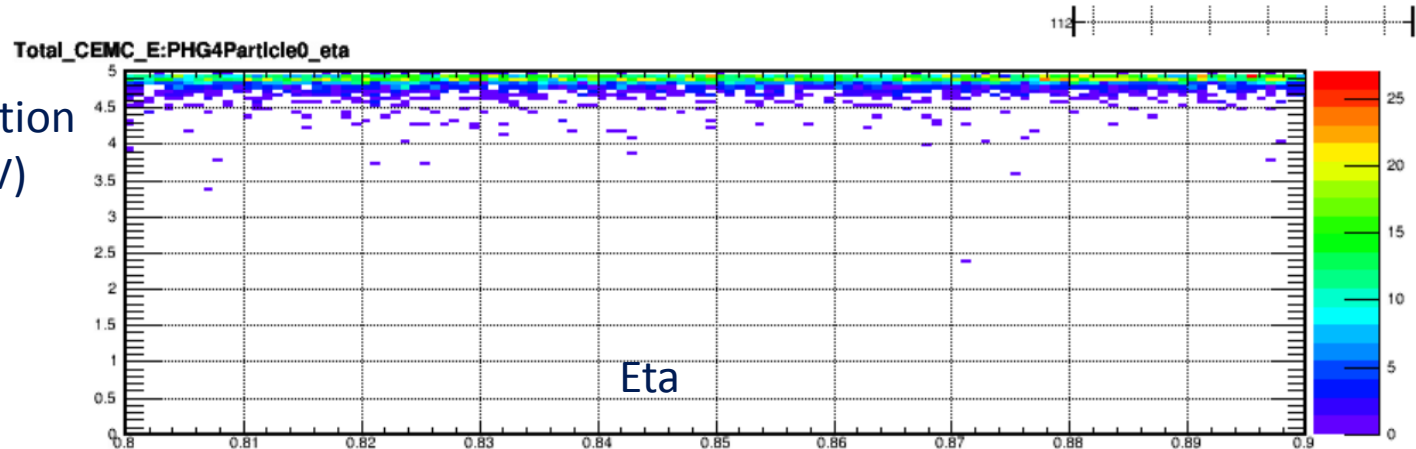


Looks smooth so far (vs eta). Still in verification $p = 5\text{ GeV}/c$ electron in sPHENIX field

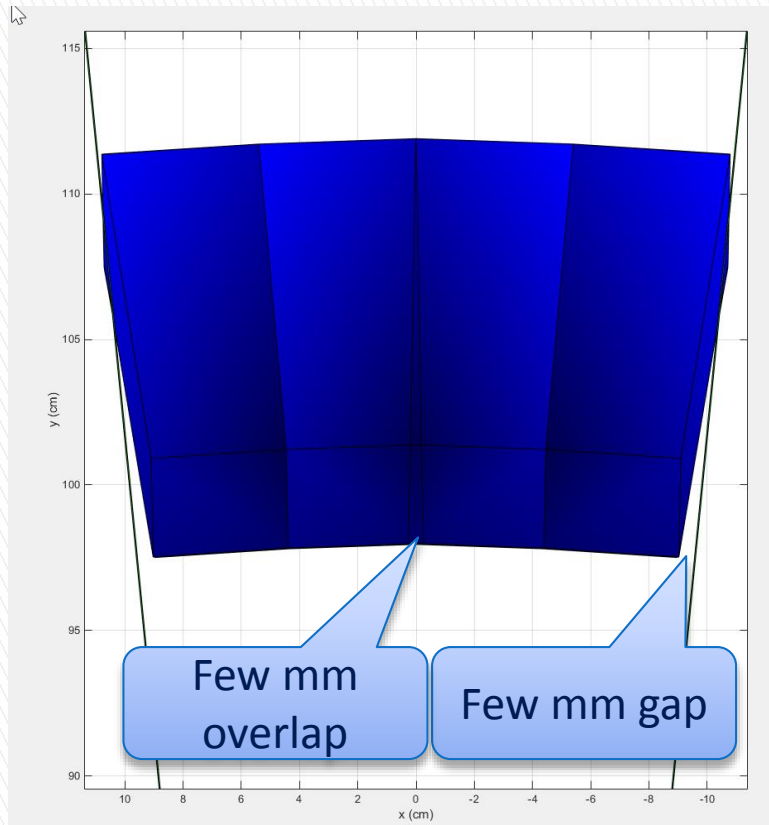
Leakage (GeV)



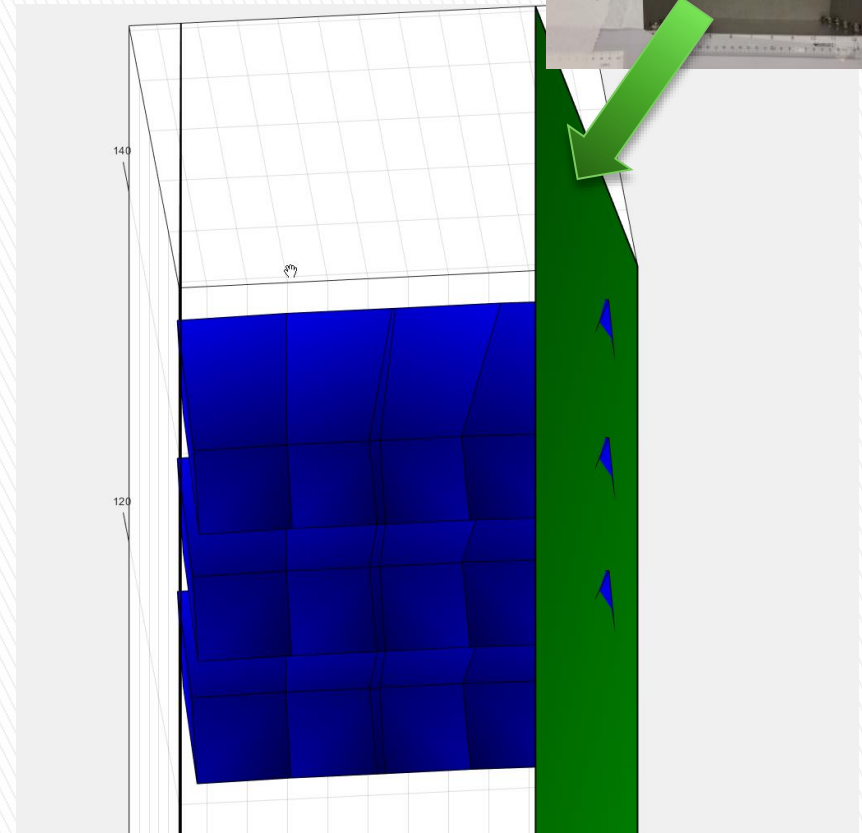
Energy deposition
in SPACAL(GeV)



However, right now there is a confliction and a gap



View of the last row of calorimeter long z axis

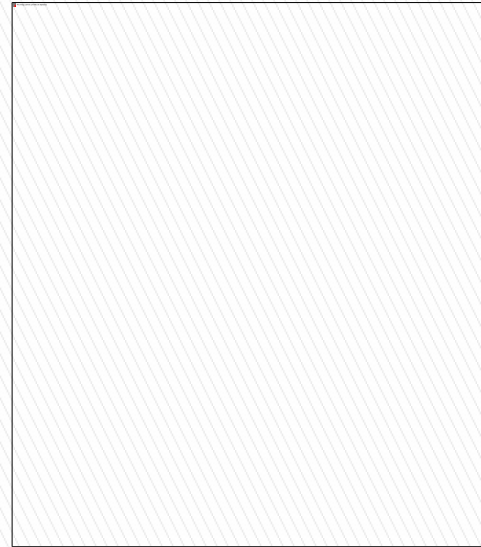


View of the last 3 rows of calorimeter from beam side

A solution

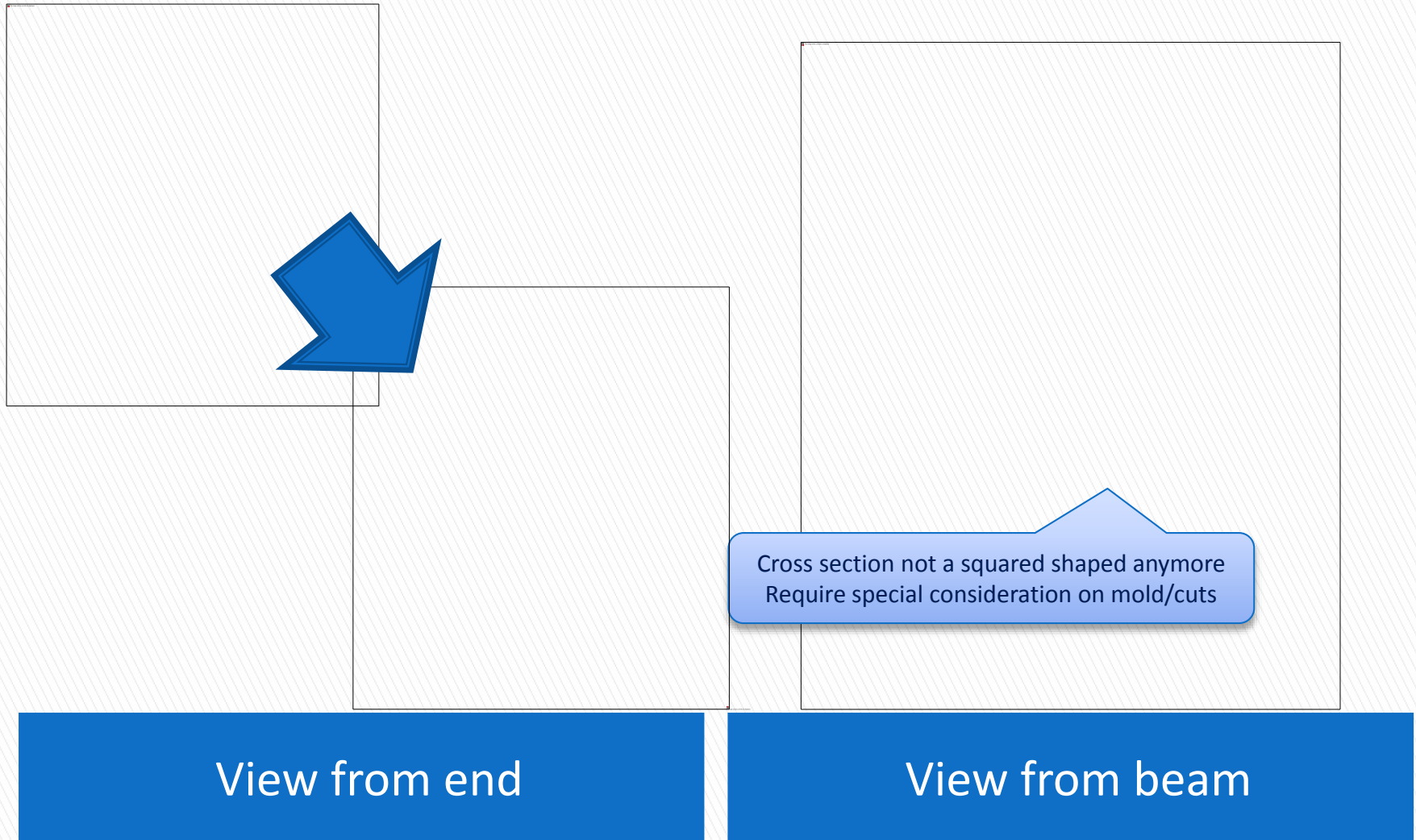


Build blocks to fit and machine
cut top and bottom to flat



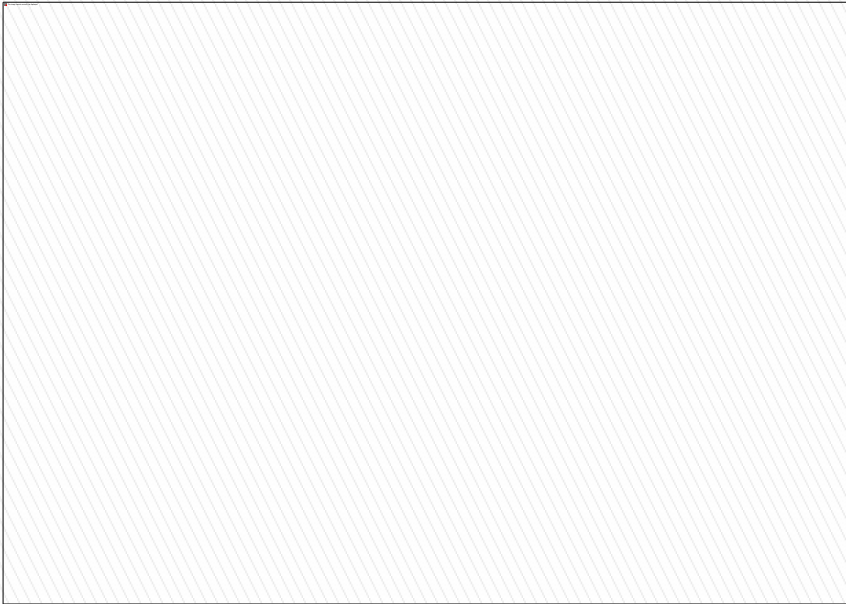
Experimental diamond cut
UIUC group

Last row after the surface cut

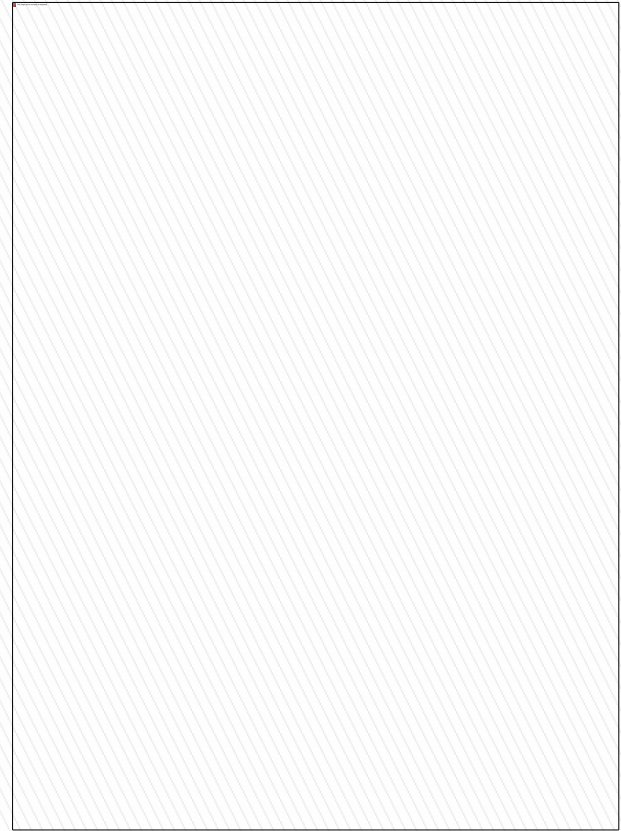


Put it all together

- 2D R-Z layout from Chris
- Regenerated in MatLab
- now ready to export into Geant4



Beam-axis view

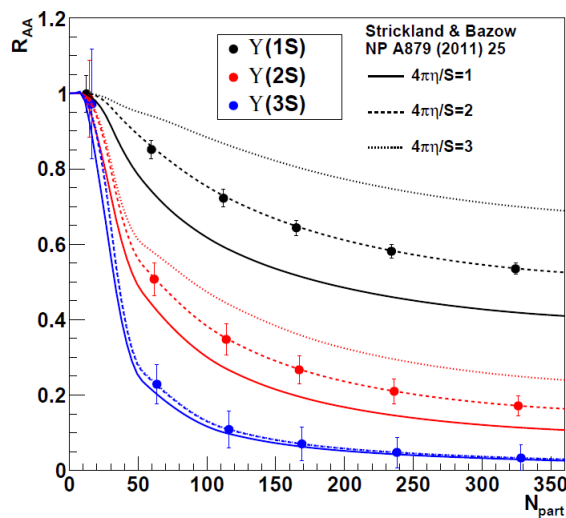


3D view

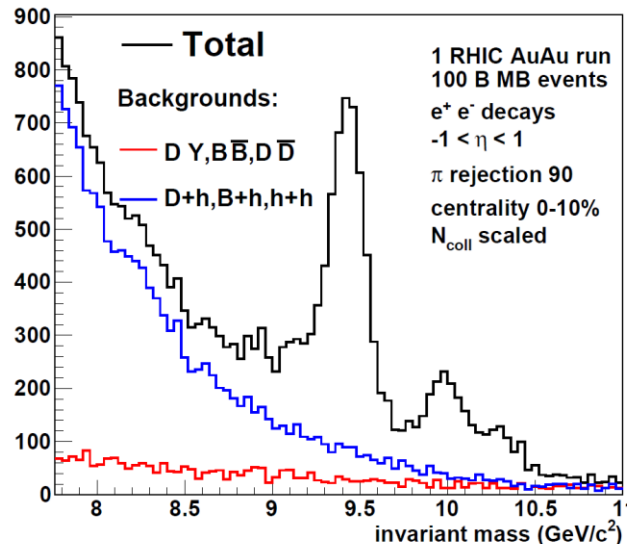
sPHENIX EMCal

1. Upsilon electron ID – main driving factor
2. Direct photon ID
3. Heavy flavor electron ID
4. Part of jet energy determination

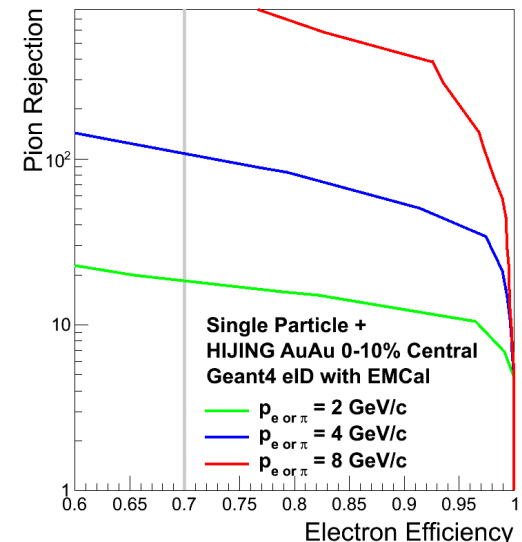
Upsilon R_{AA}



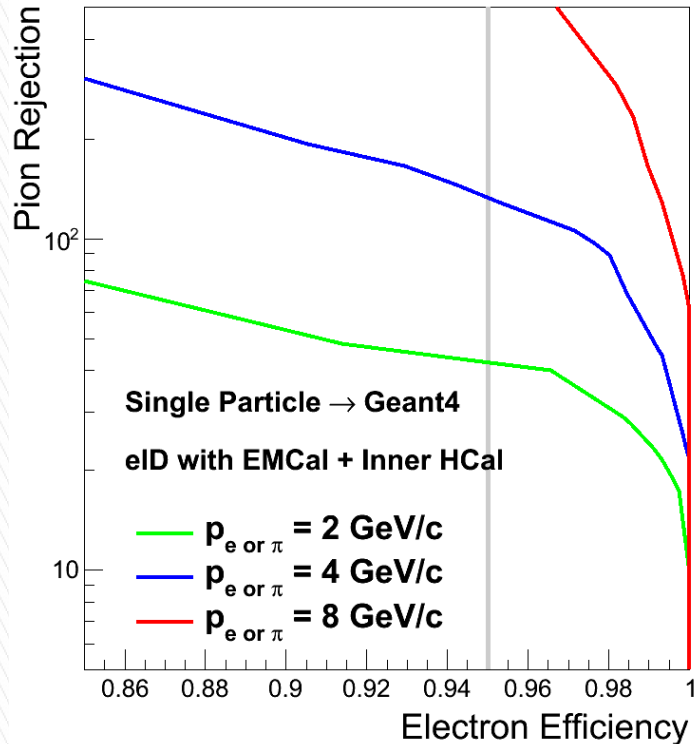
Hadron VS Upsilon



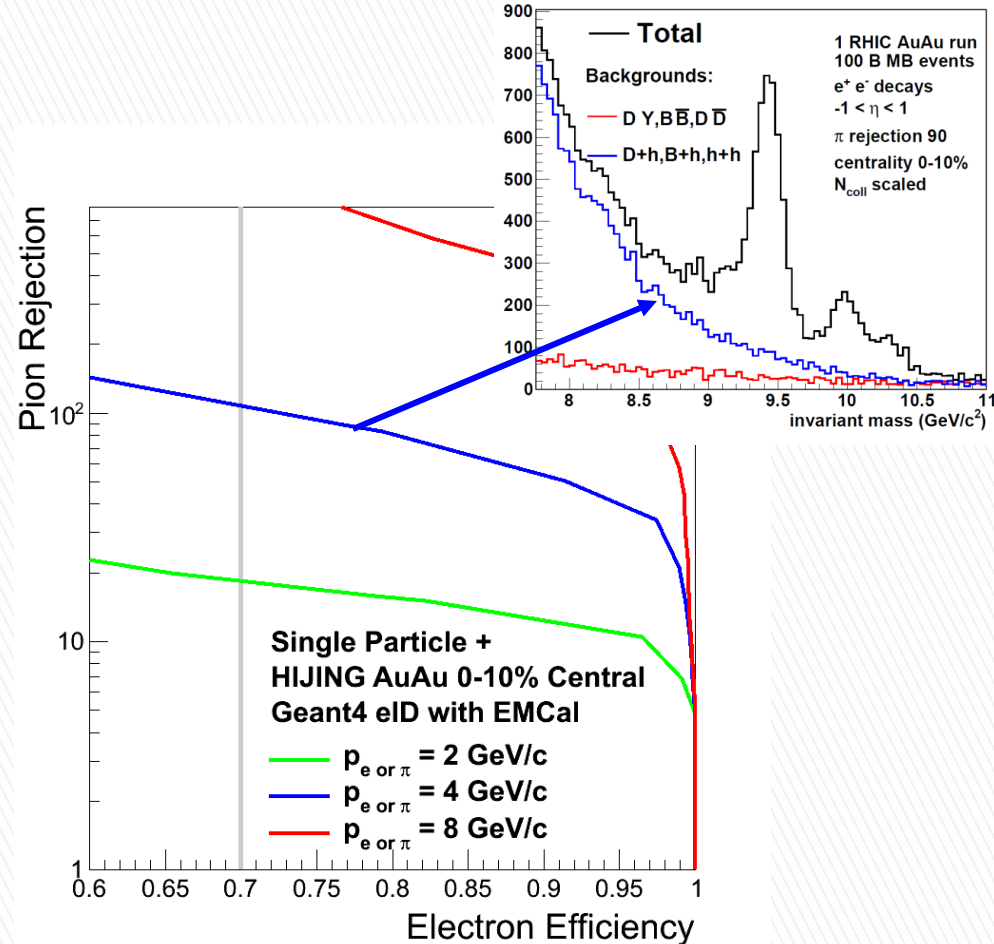
Hadron Rej. $\sim 100:1$



Compile everything together for barrel electron ID



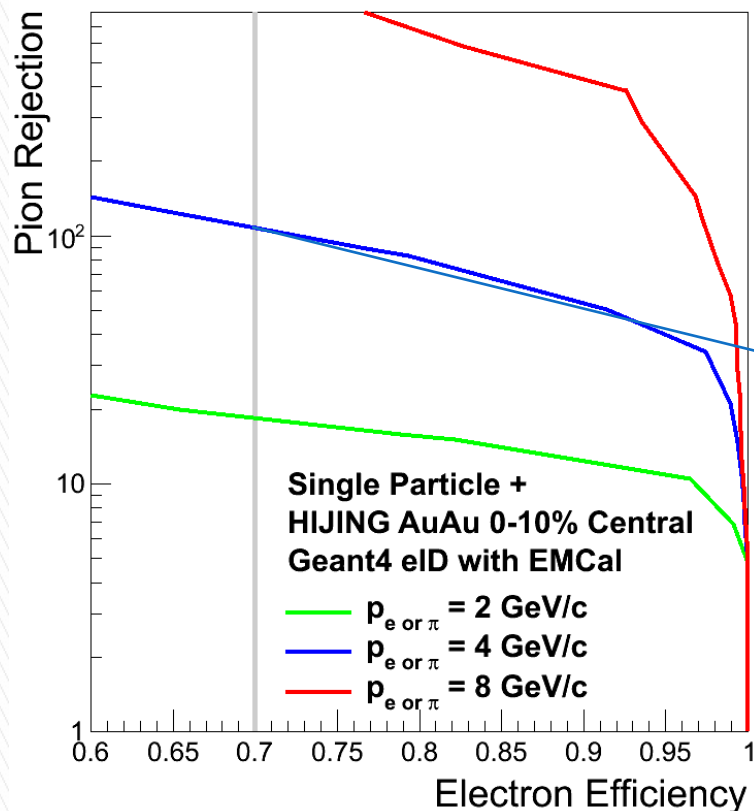
pp/ep electron ID
(EMC+HCAL)



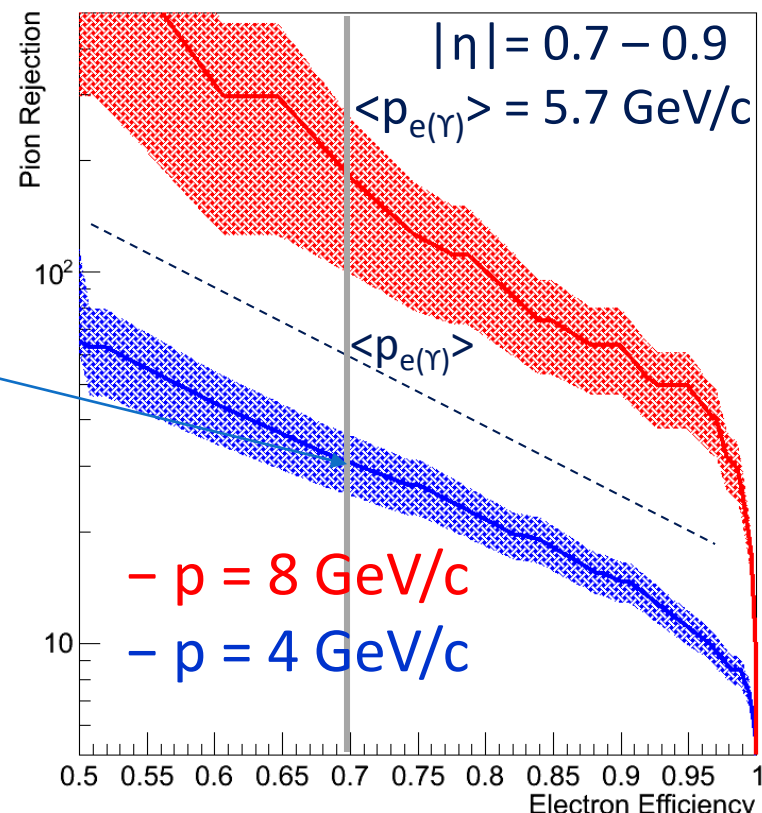
Central AA electron ID (EMC Only)

Fast group of Geant4 hit, need to re-evaluate in realistic towering!

Quantitative comparison for EID performance in Geant4 (group hits to simulate for towers)



Central rapidity, $|\eta| < 0.2$
Effectively projective in polar direction



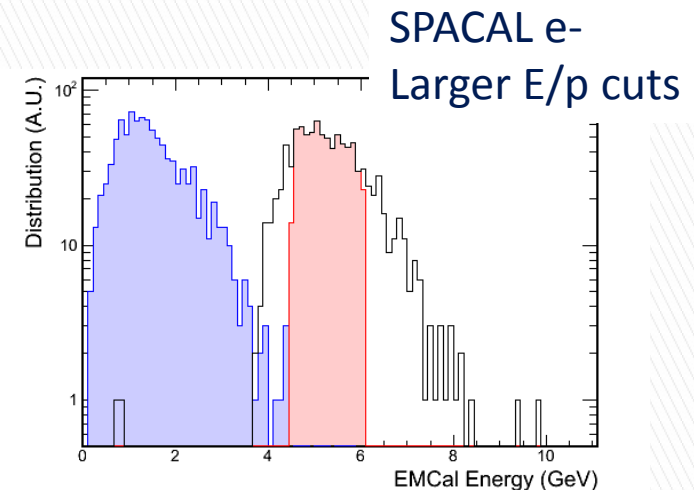
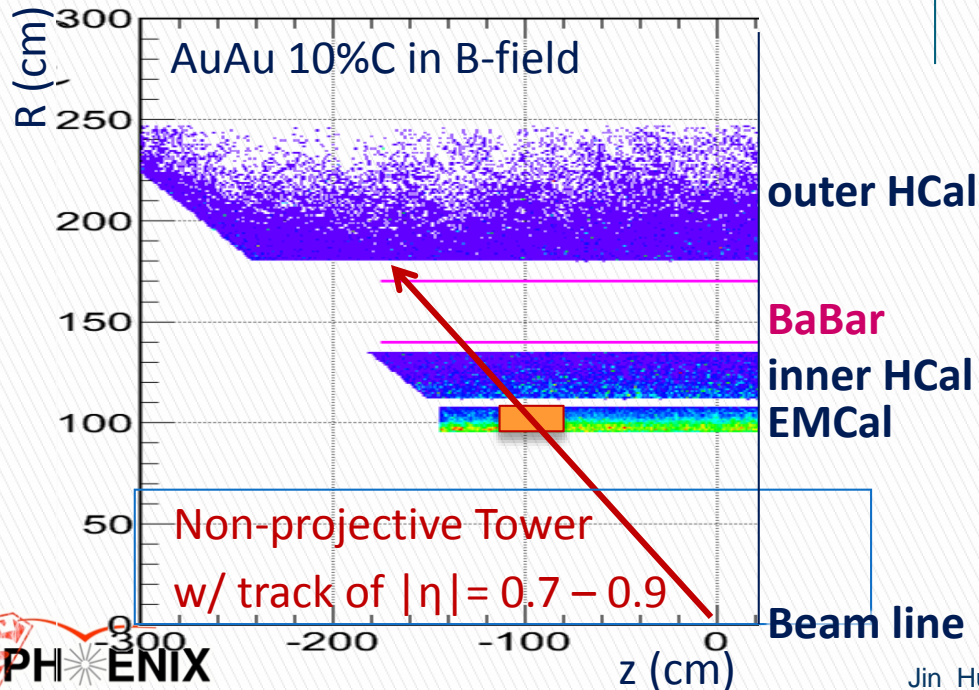
Forward rapidity, $|\eta| = 0.7 - 0.9$
non-projective in polar direction

Fast group of Geant4 hit, need to re-evaluate in realistic towering!

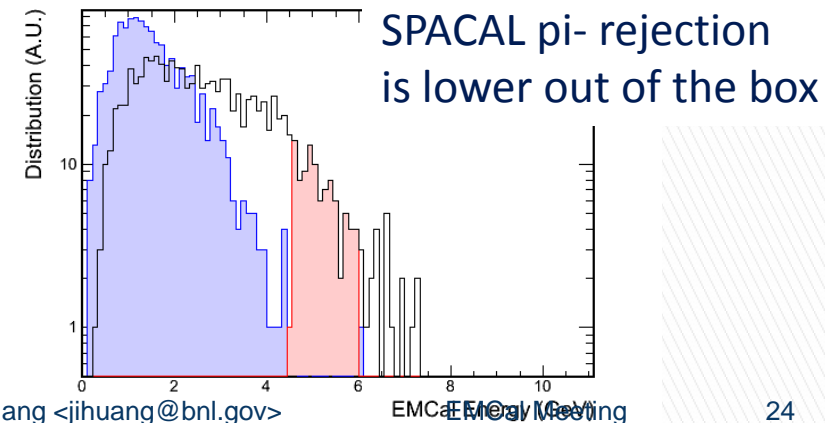
Larger pseudo-rapidity in central AuAu : under study

- Out of the box: larger $|\eta| \rightarrow$ larger background
 - Longer path length in calorimeter
 - Covers more non-projective towers
- to improve
 - Better estimate of the underlying background event-by-event (improve x1.5)
 - Use (radially) thinner ECal (improve x2)
 - Possibilities for projective towers?

- all events (w/ embedding)
- with EMCal E/p cut (w/ embedding)
- Hijing background (AuAu 10%C in B-field)

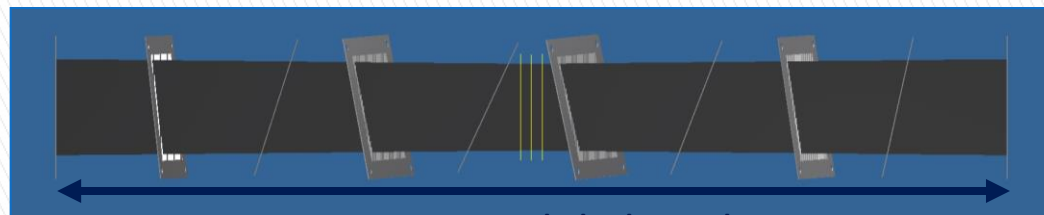
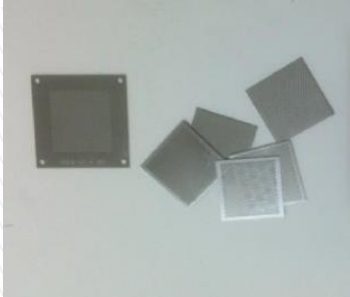
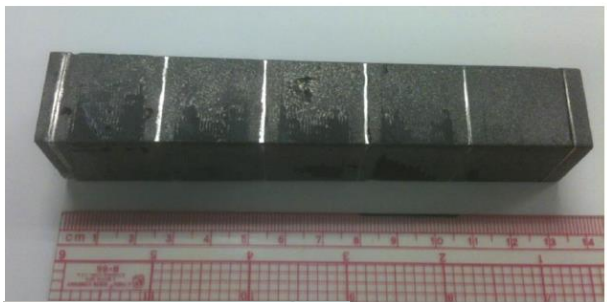


Out of box rejection $\sim 10:1$

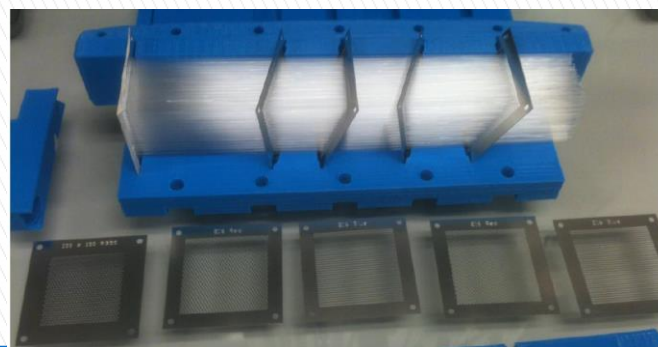


On-going R&D on 2D projective SPACAL

Sean Stoll (BNL), Spencer Locks (SBU), Jin Huang (BNL) and others



Two module length



R&D Direction 1:
Tapered step screens

R&D Direction 2:
Tilting Wireframes